Influence of machine-crop parameters on the threshability of sorghum

M. H. Saeidirad[1*], M. Esaghzade[2], A. Arabhosseini[3], S. Zarifneshat[1]

(1. *Assistant professor, Khorasan Agricultural and Natural Resources Research Center, Mashhad, Iran*;
2. *Former MSc. Student. University of Tehran, College of Abouraihan*;
3. *Associated professor, University of Tehran, College of Abouraihan*)

Abstract: The threshing section on combine harvester or thresher machine affects grain and stalk separation performance. The present study is conducted with view to optimize important operational and crop parameters influencing the threshing of sorghum. In this research, the effects of cylinder speed with four levels (13, 17, 21 and 25 m s^{-1}), concave clearance (5, 10 and 15 mm) and feed rate (420, 500 and 590 kg h^{-1}) were investigated on un-separated seed percentage, damaged seed percentage and germination. Result of ANOVA showed that cylinder speed had a significant effect on unseparated seed percentage and damaged seed percentage (P<0.01). Concave clearance created a significant effect on damaged seed percentage. Though the feed rate did not have significant effect on all adjectives, the unseparated seed percentage increased with increasing of feed rate. The thresher efficiency and damaged seed increased with increase of cylinder speed. The increase of Concave clearance from 5 to 10 mm caused that unseparated seed weight percentage increased from 0.69% to 0.78%, and damaged seed rate decreased from 13.01% to 11.01%. Generally, the best performance for sorghum threshing was given at the 21 m s^{-1} cylinder speed, 10 mm Concave clearance and 590 kg h^{-1} feed rate.

Keywords: sorghum, threshing quality, cylinder thresher

Citation: M. H. Saeidirad, M. Esaghzade, A. Arabhosseini, and S. Zarifneshat. 2013. Influence of machine-crop parameters on the threshability of sorghum. Agric Eng Int: CIGR Journal, 15(3): 55−59.

1 Introduction

Grain sorghum (Sorghum bicolor L. Moench) is one of the most versatile crops, which is capable to grow well under contrasting climate conditions. The Sorghum is grown in hot and dry regions where the summers are relatively longer. Most of the sorghum plants take 90-120 days to mature. The boot stage is within 50-60 days, flower stage is within 60-70 days, then with full grain maturity within 120 days. The sorghum is an annual or short-term perennial, culms up to 4 m or more high, sweet except in grain types, panicle is 8-40 cm long, sessile spikelet is 4- 6 mm long. The Mature glumes of sessile spikelets are either red or reddish brown or straw colored or yellowish, grain predominantly red or reddish brown (Figure 1). The sorghum grain moisture at the end of the growth period is from 18% to 20%, but 14% is the proper humidity for harvesting (Anon, 2003).

Figure 1 The panicles of sorghum

The sorghum is harvested by grain combine harvester. Increasing production of sorghum necessitates results in using of mechanization, because traditional and manual

Received date: 2012-11-11 **Accepted date:** 2013-05-22
Corresponding author: M. H. Saeidirad, Assistant professor, Khorasan Agricultural and Natural Resources Research Center, Mashhad, Iran. Email: Saiedirad@yahoo.com.

threshing is always labor consuming and uneconomical. The thresher section on combine harvester affects grain and stalk separation performance. The main purpose of this research is to investigate the effects of machinery parameters and moisture content on sorghum threshing. Threshing process studies have gone on for a long time for different crops. However, there is not enough knowledge about threshing of sorghum.

Vejasit and Salokhe (2006) studied the effect of machine-crop variables on the performance of an axial flow thresher for threshing soybean. Test results indicated that the threshing efficiency varied from 98% to 100%. The damaged grain rate and grain loss rate are less than 1% for 600 r min^{-1} cylinder speeds, 540 kg (plant) h^{-1} feed rates with 14.34% seed moisture contents, whereas it is less than 1.5% for 700 r min^{-1}, 720 kg (plant) h^{-1} with 22.8% (w.b.). The best combination of feed rate and cylinder speed at 14.3% moisture content was 600 to 700 r min^{-1} (13.2 to 15.4 m s^{-1}) and 720 kg (plant) h^{-1}.

Sinha et al. (2009) studied the effect of moisture content, concave clearance and cylinder speed on visible injury, internal injury, germination percentage and threshing efficiency of chickpea seed crop. The result showed that the cylinder speed is the most critical factor of affecting visible and internal injury extent. Moisture content adversely affected the internal injury levels in threshed seed. Cylinder speed at 8.94 m s^{-1}, concave clearance at 14 mm and moisture content at 10% were resulted seed of optimum quality with minimal visible and internal injury, and optimum threshing efficiency. Rani et al. (2001) studied the effect of moisture content and cylinder speed on threshing chickpea. They reported that maximum threshing efficiency was 97.2% at 8.9% seed moisture content with 10.1 m s^{-1} cylinder speed. Wacker (2003) studied the effect of several wheat varieties on performance of threshing. The results showed that moisture content, speed cylinder and space between concave and cylinder were effective on wheat threshing. Ajav and Adejumo (2005) evaluated effects of moisture content, space between cylinder and concave, cylinder speed and feed rate on threshing performance and damaged okra seeds. They reported that moisture content had significant effect on threshing performance and seed sprout ability. The effect of cylinder speed was significant on threshing performance alone. Khazaee (2002) reported speed cylinder and moisture content had significant effect on chickpea threshing efficiency and damaged grain percentage, but pea variety did not have significant effect on threshing efficiency and damaged grain percentage. Saeidirad and Javadi (2011) investigated the effect of thresher variables including the moisture content, cylinder type and cylinder speed, feed rate and concave clearance on weight percentage of separated seeds. Shattered stems and damaged seeds were studied in this research. The results showed that as the increase of cylinder speed from 12.8 to 16.5 m s^{-1}, the percentage of separated seed, shattered stems and damaged seed increased. The cylinder type did not have significant effect on weight percentage of separated seed, while it had a significant effect on shattered stems and damaged seeds. They reported that as moisture content increased from 7% to 13%, separated seed and damaged seed decreased from 92.8% to 90.4% and from 10.1% to 7.6% respectively. Yilmaz et al. (2008) investigated the effect of some threshing parameters such as drum speed, feed rate and concave open on sesame straw sieve in developed threshing unit. Threshing drums used were a rasp bar with tooth type. Three threshing drum speeds of 500, 700 and 900 r min^{-1} (6.5, 9.1, 11.7 m s^{-1}) were used for investigations. Three feed rate of 90, 180 and 270 kg h^{-1} and three concave open of 20, 35 and 50 mm were used. The mesh numbers of sieves were 7, 10, 14 and 18. They reported that the best performance for separation of sesame straw was given at the maximum drum speeds, minimum feed rates and concave opens experienced in this study.

2 Materials and methods

This study was carried out at Khorasan Agricultural and Natural Resource Research Center, Mashhad, Iran. The thresher unit had been designed and fabricated (Figure 2). The thresher was equipped with a rasp bar cylinder with 350 mm diameter. Two electromotors were used for cylinder and feed belt power. A digital inverter was controlling the speed of cylinder electromotor. A digital tachometer (Dt-838 model) was used for rotational speed measurement. Changing of belt velocity was done by a mechanical gearbox that caused feed rate changing. Concave clearance was changeable from 0 to 20 mm by lever handle. Six rub bars or rasp bars were mounted on the cylinder. Rasp bars were the same commercial combine bars with 400 mm length.

Figure 2 Testing thresher unit

In this study, 10 treatments were considered including: cylinder speeds (four levels: 13, 17, 21 and 25 m s^{-1}), feed rates (three levels: 420, 500 and 590 kg (plant) h^{-1} m^{-1}) and concave clearance (three levels: 5, 10 and 15 mm). The rotational speeds of thresher cylinder were calculated at 650, 850, 1,050 and 1,250 r min^{-1} for 13, 17, 21 and 25 m s^{-1} peripheral speeds respectively, with 350 mm diameter of cylinder. Experiments were performed as completely randomized block design with three replications.

The panicles of sorghum were picked by labor from the farm in Khorasan Province in Iran. The treatment samples (1 kg the panicles of sorghum) were threshed, and then grains were separated from straw using handy sieves. Eventually, weight percentage of unseparated grain, damaged grain and germination were measured for each sample. For measurement of the germination percentage, sorghum grains were grown in incubator (25°C temperature) for one week.

Statistical analysis was done on randomized complete block design applying the analysis of variance (ANOVA) using SPSS 13 software. Duncan's multiple ranges test was utilized to separate means at a 5% level of significance.

3 Results and discussion

Variance analysis of data shown in Table 1 indicates that the cylinder speed and concave clearance created significant effects on weight percentage of damaged seeds (P<0.01). The weight percentage of unseparated seeds was affected only by cylinder speed. The feed rate did not have significant effect on any characteristics.

According to Table 1, the double combination effect (cylinder speed × concave clearance) was significant on weight percentage of unseparated seeds. Also based on this statistical analyses, the triple combination effect (cylinder speed × concave clearance × feed rate) was significant at 1% level on weight percentage of unseparated seeds. In the following paragraphs, the effects of each factor on the objectives have been discussed comprehensively.

Table 1 ANOVA of threshing factors on adjectives of threshed sorghum grains (Mean of squares)

Variation source	DF	Not separated seeds/%	Damaged seeds/%	Germination /%
Cylinder speed	3	15.96**	2472.43**	107.42ns
Concave clearance	2	0.137 ns	41.55**	46.31ns
Feed rate	2	0.615 ns	3.84 ns	46.76ns
Cylinder speed × Concave clearance	6	0.049ns	5.96ns	666.81**
Cylinder speed × Feed rate	6	0.447ns	6.62 ns	0.447 ns
Concave clearance × Feed rate	4	0.238 ns	17.98 ns	26.65ns
Cylinder speed × Concave clearance× Feed rate	12	0.931ns	7.41 ns	635.83**
Error	72	0.375	8.69	126.66

Note: ns: corresponding to no significant difference.
* corresponding to significant difference at P=0.05.
** corresponding to significant difference at P=0.01.

3.1 Cylinder speed

As given in Table 2, the weight percentage of unseparated seed decreased from 1.82% to 0.22% as cylinder speed increased from 13 to 21 m s^{-1} (650 to 1,050 r min^{-1}), but significant difference was not found between 21 and 25 m s^{-1} cylinder speeds (P<0.05). This conclusion was consistent with the findings of Vejasit and Salokhe (2006), who reported that the threshing efficiency increased as cylinder speed increased from 600 to 700 r min^{-1} for threshing soybean.

According to Table 2, the weight percentage of damaged seeds increased from 4.2% to 24.91% with the increase of cylinder speed from 13 to 25 m s^{-1}. This may attribute to the fact that with the increase of cylinder speed the collision energy between grains and rasp bar increased and the seeds are loaded with the greater forces. For cumin threshing (Saeidirad and Javadi, 2011) and chickpea threshing (Khazaei, 2002) the same results were obtained.

The results showed that the cylinder speed had no significant effect on grain germination (Table 2). Nevertheless, threshing of sorghum by rasp bar thresher decreased the percentage of germination to 16%, according to 92% of the germination percentage of testifier sample.

Table 2 Means comparison of adjectives in different variations

Factors	Factor levels	Not separated seeds/%	Damaged seeds/%	Germination /%
Cylinder speed /m s^{-1}	13	1.82 a	4.2 a	75.96 a
	17	0.66 b	5.52 a	76.03 a
	21	0.22 c	14.30 b	72.09 b
	25	0.16 c	24.91c	76.23 a
Concave clearance /mm	5	0.69 a	130.1 a	73.79 a
	10	0.67 a	12.68 a	75.51 a
	15	0.78 a	11.01 b	75.93 a
Feed rate /kg h^{-1} m^{-1}	420	0.72 a	12.11 a	74.02 a
	500	0.58 a	11.99 a	76.28 a
	590	0.84 a	12.60 a	74.93 a

Note: 1) Means for the same factor and in the same column flowed followed by the same letter are not significantly different (P<0.05) according to Duncan's Multiple ranges Test;
2) The letters following the mean for the different factors are to be considered as unrelated.

3.2 Concave clearance

The effect of concave clearance on threshing performance was determined for clearances of 5, 10 and 15 mm. As given in Table 2, the weight percentage of unseparated seed increased from 0.69% to 0.78% and concave clearance increased from 5 to 15 mm, but no significant difference between concave clearance levels (P<0.05) was found.

Considering the values presented in Table 2, there is a significant difference between both 5 and 10 mm concave clearance and 15 mm concave clearance. The results showed that as concave clearance increased, the percentage of damaged grains decreased. This shows that decrease of concave clearance causes the intensity of compression, thus the weight percentage of damaged grains increased. At 15 mm concave clearances, the cushion phenomenon has reduced the intensity of collision. Saeidirad and Javadi (2011) reported that with increase of concave clearance the damaged seeds decreased and unseparated seeds increased for cumin threshing. Wacker (2003) reported a decrease in damaged seeds percentage of wheat for a wide concave clearance, which was true for the present work too.

Investigation of the double combination effects of cylinder speed and concave clearance showed that the highest difference in percentage of germination among different levels of concave clearance was related to the 25 m s^{-1} cylinder speed. The lowest percentage of grains germination was 61.9% and it happened in 5 mm concave clearance and 25 m s^{-1} cylinder speed (Figure 3).

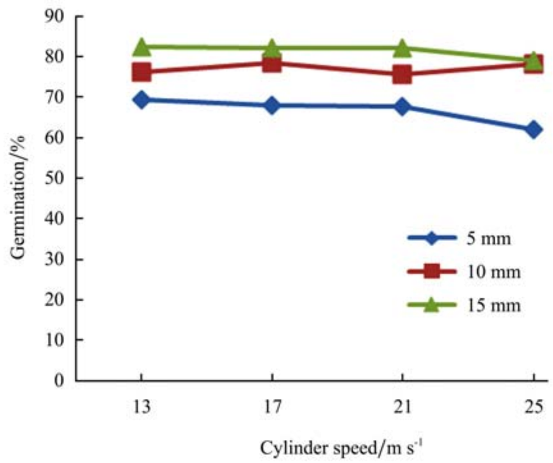

Figure 3 Combination effects of cylinder speed and concave clearance on the seeds germination percentage

3.3 Feed rate

The effect of feed rate on threshing performance was determined for 420, 500 and 590 kg h^{-1} m^{-1}. According to Table 1, the feed rate did not have significant effect on threshing performance, nevertheless the lowest weight percentage of unseparated seeds was related to 500 kg h^{-1} m^{-1} feed rate. As given in Table 2, the weight percentage of unseparated seeds increased from 0.58% to 0.84% as feed rate increased from 500 to 590 kg h^{-1} m^{-1}. This might attribute to the fact that, the material were compressed in thresher and did not contact with the cylinder rasp bars completely at higher feed rate.

Saeidirad and Javadi (2011) have documented the latter result. The excessive feed rate decrease caused the increase of weight percentage of unseparated seeds as well. Therefore, it can be concluded that the improvement of thresher performance needs to balance with feed rate.

4 Conclusion

Based on this research, the following conclusions can be drawn:

1) Result showed that the thresher performance and damaged seeds increased with the increase of cylinder speed. Yet, cylinder speed of 21 m s^{-1} was better than 13, 17 and 25 m s^{-1}. Thus, the recommendation for the design of cumin combine harvester is that the cylinder speed should be 21 m s^{-1} (1050 r min^{-1}) for efficient harvesting.

2) The concave clearance increase caused the weight percentage of unseparated seeds increased from 0.69% to 0.78% and the weight percentage of damaged seeds decreased from 13.01% to 11.01%.

3) Generally, the cylinder rasp bar thresher has the best performance at 21 m s^{-1} cylinder speed, 590 kg h^{-1} m^{-1} feed rate and 10 mm concave clearance for sorghum threshing.

Acknowledgements

The authors appreciate Khorasan Razavi Agricultural and Natural Resources Researches Center for full support of conducting this research.

References

Ajav, E. A. , and B. A. Adejumo. 2005. Performance evaluation of an okra thresher. *Agricultural Engineering International: CIGR Journal*, Vol.VII, Manuscript No.592.

Espinoza, L., and J. Kelley. 2003. *Grain Sorghum Production Handbook*. University of Arkansas, United States, Cooperative Extension Service, MP297-3M-1-04RV.

Khazaei, J. 2003. Force requirement for pulling off chick pea pods as well as fracture resistance of chick pea pods and grains. Ph.D. Thesis. Power and machinery department. Tehran University.(in Farsi).

Saeidirad, M. H., and A. Javadi. 2011. Study on machine-crop parameters of cylinder threshers for cumin threshing. *Agricultural Engineering International* :*CIGR Journal*, Vol. 13, No.2, Manuscript No 1746.

Sinha, J. P., I. S. Dhaliwal,, S. N. Sinha, and A. Dixit. (2009). Studies on Machine-Crop Parameters for Chickpea Seed Crop Threshing. *Agricultural Engineering International: CIGR Ejournal*, Vol. XI. 2, Manuscript No.1428.

Ukatu, A. C. 2006. A modified threshing unit for soya beans. *Biosystem Engineering*, 95(3): 371-377.

Vejasit, A., and V. M. Salokhe. 2004. Studies on machine-crop parameters of an axial flow thresher for threshing soybean. *Agricultural engineering international: CIGR Journal*. Volume VI, Manuscript No.522..

Wacker, P. 2003. Influence of crop properties on the threshability of cereal crops. *American Society of Agricultural Engineers* ,Publication Number 701P1103e, ed. Graeme Quick.

Yilmaz, D., I. Akinci, and M. I. Cagiran. 2008. Effect of some threshing parameters on sesame separation. *Agricultural Engineering International: CIGR Ejournal*, Vol. X. Manuscript No.1236.